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Evaluation of turpentine as a bird-repellent seed treatment

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These experiments explored the repellency of turpentine to brown-headed cowbirds (*Molothrus ater*), common grackles (*Quisculus quiscula*) and red-winged blackbirds (*Agelaius phoeniceus*). Phytotoxicity of turpentine to treated seeds also was assessed. Concentrations as low as 0.13% (w/w) were repellent to cowbirds in both one-cup and two-cup tests. However, grackles and red-wings showed no avoidance of turpentine concentrations as high as 5.0%. No concentration was phytotoxic. Although turpentine apparently does not interfere with seed germination, it has limited value as a bird-repellent seed treatment.

Keywords: blackbird; chemosensory; depredation; repellent; turpentine

Few effective chemical repellents are legally available for the control of avian depredation (Mason and Clark, 1992). As a result, research efforts are being focused on the development of new repellent products (e.g. Mason, Adams and Clark, 1989; Mason and Turpin, 1990; Avery and Decker, 1991). One candidate repellent is the terpenoid *d*-pulegone (Mason, 1990). Concentrations as low as 0.01% (w/w) reduce consumption by birds in both one-cup and two-cup tests (Mason, 1990).

Avoidance of *d*-pulegone is not unexpected. Terpenoids affect many interactions between plants and animals, and act as phytoalexins, insect anti-feedants and defensive agents (Harborne, 1991). Some are highly toxic, and others interfere with animal growth and reproduction (Harborne, 1991). A reasonable inference is that other, more readily available turpenoid materials might also have bird-repellent properties.

Turpentine may be one such material, and unpublished reports suggest that it is widely, albeit surreptitiously, used to repel birds (W. R. Bonwell, personal observation). The experiments described here were designed to evaluate the effectiveness of turpentine as a blackbird repellent. Turpentine is both insect (Duke, 1985) and rodent repellent (Janzen, 1978), and farmers claim that it can be used as a seed treatment to reduce bird damage to sprouting crops (W. R. Bonwell, personal observation). Because turpentine contains a number of allelopathic monoterpenes (Radwan and Ellis, 1975), its effect on seed germination also was examined.

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Materials and methods

Chemicals

Turpentine (CAS 8006-64-2) was obtained from a manufacturer (Union Camp, Inc., Princeton, NJ, USA).

Birds

Adult common grackles (*Quiscula quisculus*), red-winged blackbirds (*Agelaius phoeniceus*), and brown-headed cowbirds (*Molothrus ater*) were decoy-trapped in Sandusky, Ohio and air-shipped to our laboratory in Philadelphia, Pennsylvania, USA. These birds were studied for two reasons: first, they damage seeds and sprouting crops (e.g. Stickley and Guarino, 1972; Dolbeer, Stickley and Woronecki, 1978/1979; Avery and Decker, 1991); second, they display marked differences in chemosensory ability. For example, whereas cowbirds possess a relatively acute sense of smell (Clark and Mason, 1989), red-wings and grackles are less sensitive (Mason *et al.*, 1991a; J. R. Mason, personal observation).

Upon arrival, the birds were weighed and individually caged (cage dimensions 61 × 36 × 41 cm) under a 12 h/12 h light/dark cycle. During a 2-week adaptation period before testing, all birds were given free access to Purina Flight Bird Conditioner (referred to below as chow; Purina Mills, St Louis, MO, USA) and tapwater.

Behavioural tests

Both one-cup and two-cup tests were performed. The former test is a more stringent test of repellency than the latter, because birds must either eat repellent-treated chow or not eat at all. Conversely, two-cup tests are more sensitive than one-cup tests for revealing discrimination between foods, because birds can avoid repellent merely by feeding on untreated chow alone (Mason *et al.*, 1989).

One-cup tests. Each species was tested using the same procedure. For all, the 2-week adaptation period was followed by 4 days of pretreatment. On each day, between 08:00 and 13:00, birds were presented with a single cup (10 cm diameter) containing 10 g sunflower seeds and 10 g cracked corn. At the end of each session, the sunflower seeds and corn remaining in the cup were separated and weighed. Birds were permitted free access to chow and tapwater from 13:00 until 08:00 on the following day.

At the end of the pretreatment period, birds were assigned to five groups (n = four per group for red-wings and grackles; n = five per group for cowbirds) on the basis of overall mean consumption. The bird with the highest consumption was assigned to the first group, that with the next highest to the second group, and so forth, in a counterbalanced fashion. This ensured that groups were balanced with respect to intake (Clark and Mason, 1993).

On each of the next 4 days between 08:00 and 13:00, all birds were given one cup containing 10 g turpentine-treated sunflower seeds and 10 g turpentine-treated cracked corn. We used these two food types for three reasons: first, they provided a more balanced diet for the birds; second, they allowed us to assess whether turpentine-related avoidance (if any) was affected by food type; finally, we were able to perform germination tests (see below) with the sunflower seeds.

Group 1 was presented with 1% (w/w) turpentine, group 2, 0.5% turpentine, group 3, 0.25% turpentine and group 4, 0.13% turpentine. At the end of each treatment period, consumption was recorded. Birds were permitted free access to chow and tapwater until 08:00 on the following day.

One-choice tests were repeated with naïve grackles and red-wings, using two progressively higher concentration ranges of turpentine (i.e. 1.13, 1.25, 1.5, 2.0; and 2.0, 3.0, 4.0, 5.0% w/w). No additional cowbirds were tested. Testing procedures used with these higher concentrations were identical to those described above.

Two-cup tests. Because of convenience and logistical constraints, birds used in the one-cup tests again served in two-cup tests. Experiments were separated by 3 weeks; during this rest period, birds were permitted free access to chow and tapwater.

As in one-cup tests, all birds experienced 4 days of pretreatment. On each day, birds were presented with two feed cups at 08:00. Each cup contained 5 g sunflower seeds and 5 g cracked corn. At 13:00, the sunflower seeds and cracked corn remaining in each cup were separated and weighed. Birds were permitted free access to feed and water from 13:00 until 08:00 on the following day. After the fourth session, the birds were assigned to four groups (n = four per group) on the basis of consumption, as described above.

A 4-day treatment period immediately followed pretreatment. All birds were presented with two cups, each containing 5 g sunflower seeds and 5 g cracked corn. The seeds and corn in one cup were mixed with different amounts of turpentine. Each group was presented with a different turpentine concentration: group 1 was presented with 1% (w/w) turpentine, group 2, 0.5% turpentine, group 3, 0.25% turpentine and group 4, 0.13% turpentine. As in pretreatment, cups were removed from the cages and consumption was recorded at 13:00. Birds had free access to chow and tapwater overnight.

Germination tests

Six 50 g samples of sunflower seeds were mixed with different amounts of turpentine to create concentrations that bracketed those used in behavioural tests (i.e. 0.0, 1.25, 2.50, 3.75, 5.0%, w/w). From each of these samples, 24 seeds were selected randomly, planted in vermiculite, and held under continuous illumination at 23°C for 10 days. On each day, the number of seeds in each sample that germinated was recorded.

Analysis

One-cup tests. Three-factor analyses of variance (ANOVA) with repeated measures between periods (two levels) were used to assess total consumption, as well as consumption of cracked corn and sunflower seeds, *per se*. The independent factors in these analyses were species (three or two levels) and concentrations (four levels). Because all analyses showed the same pattern of results, only the evaluations of total consumption are reported here.

Two-cup tests. A three-factor ANOVA with repeated measures between cups (two levels) was used to assess consumption. As in the analyses of one-cup data, the independent factors in the two-cup analysis were species (three levels) and concentrations (four levels). Because there were no differences in the way that birds behaved towards sunflower seeds and cracked corn in one-cup tests, only total consumption was assessed in two-cup tests.

Germination tests. Overall germination success after 10 days was evaluated in a one-factor independent measures (concentration) ANOVA.

In all cases, Tukey tests (Winer, 1962) were used to isolate significant differences among means ($p < 0.05$).

Results

Behavioural tests

One-cup tests, 0.13–1.0% turpentine. Grackles ate

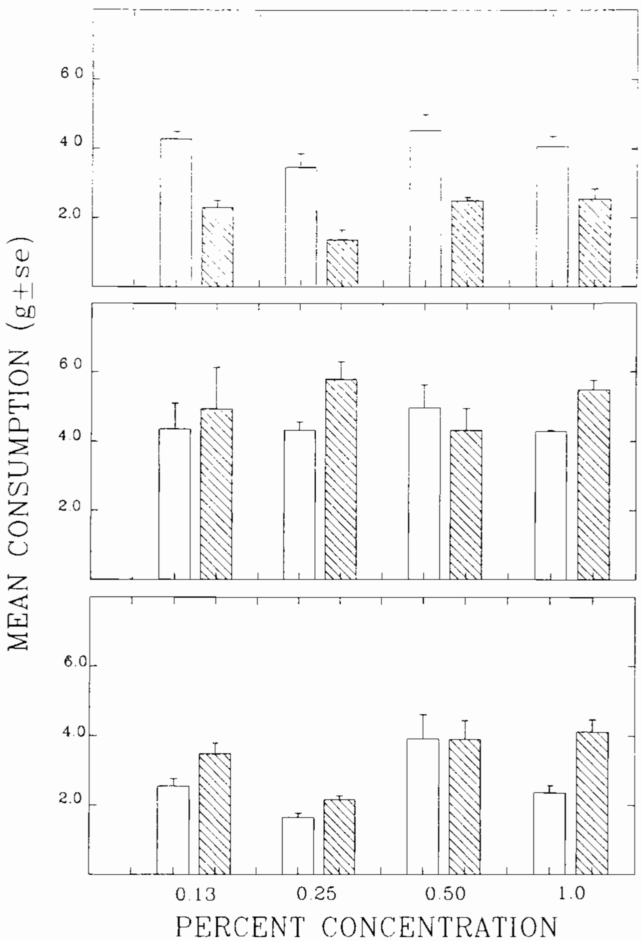

Figure 1. Mean consumption of feed in one-cup tests before (□) and after (▨) treatment with turpentine, by (top) cowbirds, (middle) grackles and (bottom) red-wings. Turpentine concentrations ranged between 0.13 and 1.0% (w/w). Only cowbirds avoided treated feed

more than cowbirds or red-wings ($F = 31.9$; 2,40 d.f.; $p < 0.00001$) and, overall, slightly less was eaten during the treatment period than during pretreatment ($F = 9.0$; 1,40 d.f.; $p < 0.005$). However, examination of the significant interaction between species and period ($F = 5.6$; 2,40 d.f.; $p < 0.007$) showed that only cowbirds reduced consumption of turpentine-treated feed relative to pretreatment (*Figure 1*).

One-cup tests, 1.13–2.0% and 2.0–5.0% turpentine. For both of the higher concentration ranges, there were species differences in overall consumption (1.13–2.0%: $F = 12.1$, 1,24 d.f.; $p < 0.002$; 2.0–5.0%: $F = 9.8$; 1,24 d.f.; $p < 0.002$). Grackles ate more than red-wings; otherwise, there were no significant differences (p values > 0.25; *Figures 2, 3*).

Two-cup tests. Grackles ate slightly more than red-wings, and red-wings ate more than cowbirds ($F = 88.7$; 2,36 d.f.; $p < 0.00001$). Examination of the interaction terms revealed a significant effect between species and periods ($F = 6.8$; 2,36 d.f.; $p < 0.003$). As in one-cup tests, only cowbirds avoided turpentine-treated feed ($p < 0.05$; *Figure 4*); otherwise, there were no significant differences ($p > 0.25$).

Germination tests

There were no significant differences among turpentine concentrations (p values > 0.40). None of the turpentine-treated samples showed significantly lower germination success than the control sample (*Figure 5*).

Discussion

Turpentine was neither phytotoxic nor particularly repellent, even at concentrations as high as 5.0% (w/w). By comparison, the avian irritant methyl anthranilate substantially reduces consumption by passerines at concentrations $\geqslant 0.4\%$ (w/w) (e.g. Mason *et al.*, 1989). Only cowbirds avoided treated feed and, even for that species, repellency appeared to diminish over days, suggesting that the aversion to turpentine might be overcome.

The fact that cowbirds were more sensitive than either grackles or red-wings is consistent with evidence that cowbirds possess more acute chemosensory abilities than grackles and red-wings (Clark and Mason, 1989; Mason *et al.*, 1991a). The underlying explanation for this difference remains obscure. Anatomically, all three species are microsmatic (J. R. Mason, personal observation) and ecologically, there seems to be no a priori reason for the greater chemical sensitivity of the cowbirds.

More generally, the low sensitivity of all three species to turpentine is consistent with the general observation that birds are insensitive to chemicals that act as irritants to mammals (Mason and Otis, 1990;

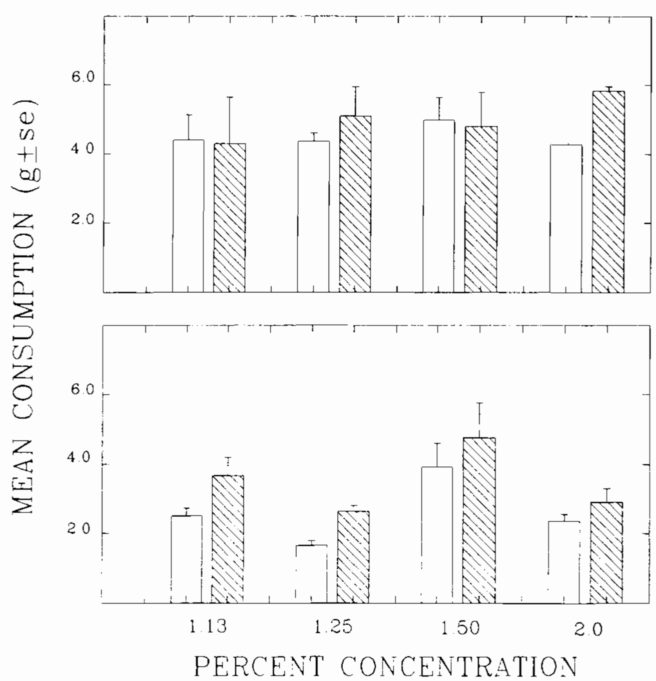

Figure 2. Mean consumption of feed in one-cup tests before (□) and after (▨) treatment with turpentine, by (top) grackles and (bottom) red-wings. Turpentine concentrations ranged between 1.13 and 2.0% (w/w). Neither species avoided treated feed

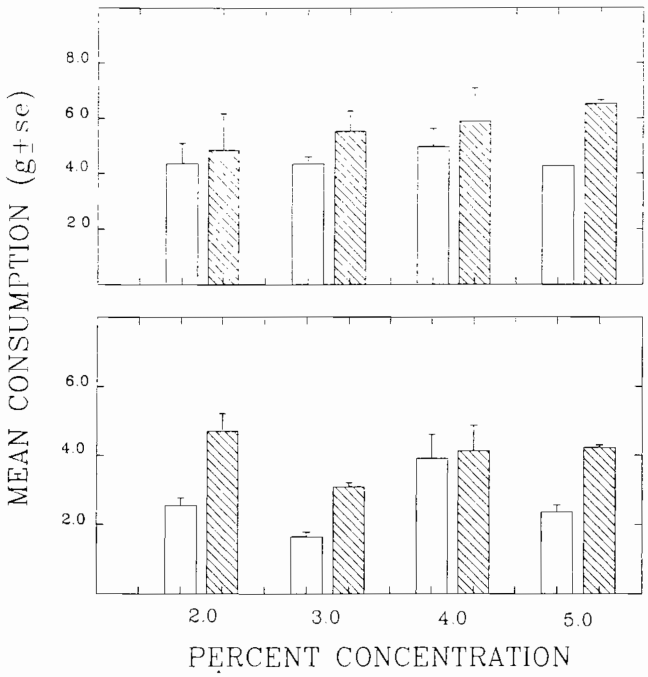

Figure 3. Mean consumption of feed in one-cup tests before (□) and after (▨) treatment with turpentine, by (top) grackles and (bottom) red-wings. Turpentine concentrations ranged between 2.0 and 5.0% (w/w). Neither species avoided treated feed

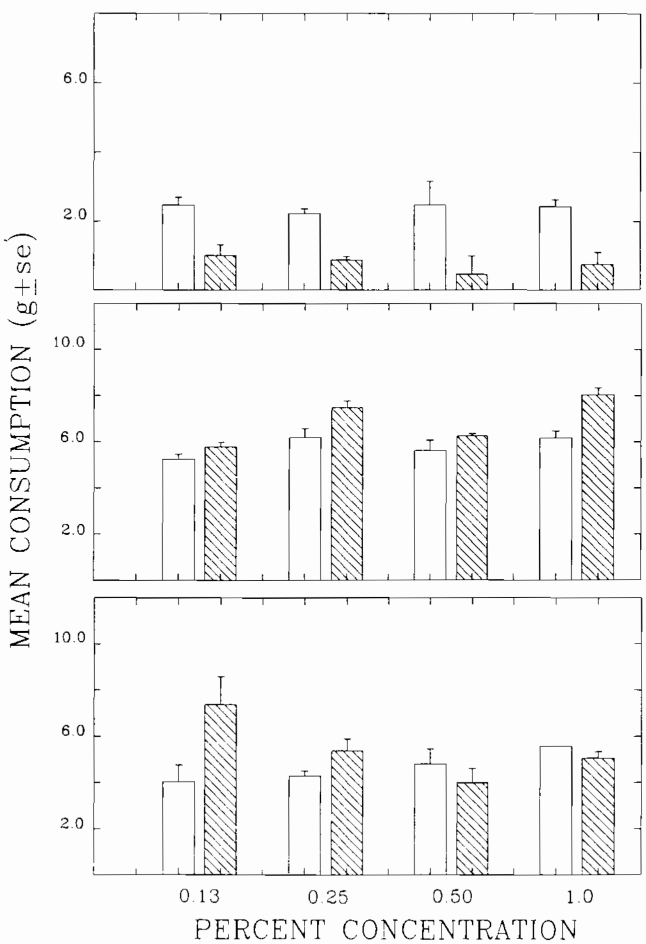

Figure 4. Mean consumption of (□) untreated or (▨) treated feed in two-cup tests by (top) cowbirds, (middle) grackles and (bottom) red-wings. Turpentine concentrations ranged between 0.13 and 1.0% (w/w). For graphical reasons, the vertical axis range for cowbirds is half that for grackles and red-wings. Only cowbirds avoided treated feed

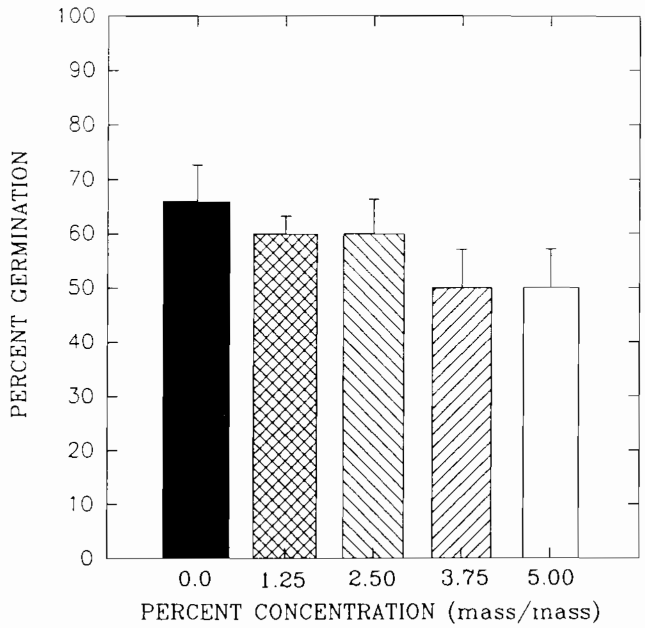

Figure 5. Percentage germination, after 10 days, of sunflower seeds treated with turpentine at concentrations ranging from 0.0 to 5.0% (w/w). No turpentine concentration significantly reduced germination

Mason *et al.*, 1991b; Norman, Mason and Clark, 1992). Other strong irritants to which birds appear relatively indifferent include piperine (the irritant in black pepper), allyl isothiocyanate (the irritant in black mustard), ammonia, gingerol and zingerone (the irritants in ginger), and capsaicin (the irritant in jalapenos). Many of these taxon-specific differences are very marked. In the case of capsaicin, at least some species of birds appear to be about two or three orders of magnitude less sensitive than mammals (e.g. Szolcsanyi, Sann and Pierau, 1986). We have speculated that the differential sensory effects may reflect a selected response related to the reproductive strategy of capsicum-producing plants. Specifically, capsaicinoids may exploit the separately evolved sensory systems of the two taxa (Mason, Clark and Shah, 1992) and may selectively repel mammalian seed predators but not avian seed dispersers. Whether or not the same arguments could be made with respect to other plant-produced irritants is not known.

Management implications

No effective chemical repellents are legally available for the control of avian depredation (Mason and Clark, 1992). Not surprisingly, farmers have begun to seek alternatives on their own. One apparently common alternative is the use of turpentine as an aversive seed treatment (W. R. Bonwell, personal observation). Turpentine may, in fact, repel rodents (e.g. Janzen, 1978; Bell and Harestad, 1987) and, perhaps, other mammals such as deer (e.g. Connolly *et al.*, 1980). However, in the evaluation of three blackbird species, described here, turpentine repelled only cowbirds and, even then, avoidance seemed transient. Grackles and red-wings were unaffected. As grackles and red-wings are the avian species most commonly implicated in instances of seed depredation and sprout pulling (e.g. Stickley and Guarino, 1972; Avery and Decker, 1991), we conclude that turpentine seed treatments have little value against avian depredation.

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